

- 16 -

engine as when the CSF was present in order to maintain the same engine-out NOx levels. The valve provides an adjustable back pressure for the step load tests discussed below.

5 Steady state tests were run at 1800 RPM on the engine. Engine load was varied to achieve different exhaust temperatures. The steady state test conditions and correspondence to drawings to be subsequently discussed are summarized below in Table 1:

10

Table 1

Steady State Speed of 1800 rpm

Load	SCR Cat Inlet T	Exhaust Flow (SCFM)	SCR Cat GHSV (1000 Hr-1)	NOx (ppm)	Figures
14%	200EC	285	28.3	214	6,7
60%	345EC	471	46.9	420	4,5
15 100%	468EC	515	51.3	770	2,3

At each of these steady state conditions urea solution was injected into the exhaust at different rates to vary the NSR level. Emissions were measured for each NSR level and the NOx conversion and NH₃ slip (break through) determined. This was done for the CSF and ZNX SCR catalyst configuration and the ZNX SCR Catalyst alone configuration. The results are discussed below. The results based on the FTIR measurements are shown, but these were in good agreement with the chemiluminescence results.

20

25

Figure 2 shows the NOx conversion levels as a function of NSR for the CSF and ZNX SCR configuration indicated by

RECEIVED
OCT 5 2001
TC 1700

NOx conversion than did the ZNX SCR alone configuration. The CSF and ZNX configuration exhibited no NH₃ break through over the test cycle.

The OICA Cycle results also showed that final HC emissions were reduced significantly by either configuration. However, with the CSF up-stream the HC's were removed prior to the SCR catalyst but with the ZNX SCR catalyst alone configuration both HC's and NOx had to be converted over the SCR catalyst. The ZNX SCR catalyst alone configuration exhibited little CO conversion as might be expected. With CSF catalyst 12 up-stream, a high level of CO conversion was obtained over CSF catalyst 12 presenting a low CO exhaust to SCR catalyst 14. This is probably not that significant for SCR catalyst activity, but overall, tailpipe CO is substantially decreased with the CSF present.

Table 2 set forth below summarizes the ESC test as follows:

Table 2
ESC Test Data

Configur ation	Temperatures, deg C			Avg. NSR	Avg. NOx Conv. %	Max NH ₃ Slip ppm	SCR Out Emissions, g/kW-hr		
	CSF In	SCR In	SCR Out				HC	CO	NOx
Fig. 10 SCR 300 HP		357	368	0.985	67.3%	241	0.04	0.83	2.07
Fig. 11 CSF+SCR 300 HP	399	367	376	0.976	85.1%	0	0.03	0.07	0.92
Fig. 12 SCR 180 HP		288	300	0.921	58.2%	310	0.07	1.09	2.51

Fig. 13 CSF+SCR 180 HP	321	296	303	0.963	89.9%	0	0.04	0.1	0.61
------------------------------	-----	-----	-----	-------	-------	---	------	-----	------

5 The results of the OICA Cycle tests were consistent with the steady state tests showing improved performance of the CSF and SCR catalysts configuration compared with the SCR catalyst alone configuration for total NO_x conversion and control of NH₃ break through.

10 1) In general summary, the Steady State Tests showed:

a) A slight advantage of CSF and SCR over SCR alone as a function of NSR at high inlet temperature (470EC). Both configurations attained ca.80-90% NO_x conversion for NSR = 0.8-0.9;

15 b) For lower inlet temperatures (345EC & 200EC) the CSF and SCR configuration gave substantially better NO_x conversion than the SCR alone configuration at all NSR levels, but especially at higher NSR's. CSF and SCR attained 70-90% NO_x conversion for NSR = 0.7-0.9. Activity
20 for NO_x conversion for SCR alone decreased with decreasing inlet temperature while CSF and SCR maintained activity;

c) The CSF and SCR system gave 70% NO_x conversion at 200EC for NSR 0.7-0.85 and SCR alone configuration gave only 10%. CSF and SCR is therefor viable for light load and
25 light duty diesel applications;

d) The more effective utilization of the reductant by this invention results in less unreacted ammonia leaving the catalyst. In these experiments virtually all of the available reductant (ammonia) was used to reduce NO_x and
30 therefore no unreacted ammonia could be detected at the catalyst exit;
and,

- 27 -

catalyst. These HC's could also occupy catalyst active sites thereby interfering with the SCR activity.

CSF 12 used for the tests was formulated with a relatively high Pt loading level (75 g/ft^3). FTIR exhaust emissions analysis showed that consistent with known operating characteristics of diesel engines, the engine-out NOx was primarily in the form of NO with a very small level of NO₂. Thus, the NO₂/NOx ratio was very low. This was the nature of the NOx entering CSF catalyst 12. The exhaust gas coming out of CSF catalyst 12, however, showed significantly higher levels of NO₂ and the NO₂/NOx ratio was also higher than engine-out. That is, the nature or composition of the NOx entering ZNX SCR catalyst 14, i.e., at 22B, had a higher concentration of NO₂ than that emitted from engine 15, i.e., at 22A. The NO₂ molecule is generally considered to be a more reactive species than the NO molecule. Further, NO₂ is more polar and thus potentially more adsorbable on catalyst surfaces than NO. Thus, exhaust gases having a NOx composition with a higher NO₂/NOx ratio may exhibit enhanced NOx reduction activity in the SCR reaction. The NO₂/NOx ratios for the steady state test conditions described above at the various sampling points (shown in Figure 1) are given in Table 3 below:

Table 3
NO₂/NOx Ratios

		Engine-Out	Engine-Out	CSF-Out	ZNX-Out (NSR >0.8)
Load	Temp	NOx (ppm)	NO ₂ /NOx Ratio 22A	NO ₂ /NOx Ratio 22B	NO ₂ /NOx Ratio 22C, 22D
100%	468EC	770	0.3%	12.7%	0.0%
60%	345EC	420	1.2%	45.4%	0.0%

- 28 -

14%	200EC	214	4.6%	28.2%	0.0%
-----	-------	-----	------	-------	------

The enhanced levels of CSF-out NO₂ can be seen in Table 3 as a significant increases in the NO₂/NO_x ratio for each of the steady state test conditions. Furthermore, no NO₂ could be found in the SCR catalyst-out sampling position. Thus, 100% of the NO₂ was converted over SCR catalyst 14.

The preferred embodiment uses a solution of urea in water injected into the exhaust. Figure 1 is schematically reproduced in Figure 14A in its commercially implemented sense and reference numerals used in Figure 1 will apply to figure 14A where possible. As is well known, various arrangement are used in which aqueous urea shown on one line 70 with air on another line 71 are mixed in various nozzle configurations shown as mixing station 72 to pulse or meter (schematically indicated by valve 74) a precise amount (stated as an NSR value) of ammonia which is injected as a spray from a nozzle into the exhaust stream. Valve 74, in turn, is controlled or regulated by a computer (not shown) typically the engine's ECM (electronic command module) which interpolates sensor (not shown) readings of the exhaust gases to establish a reductant flow sufficient to match a desired NSR value. It is known that an aqueous urea solution tends to lower the exhaust temperature which is not desirable because of the SCR active window temperature range. The data has shown, however, that the temperature at which the SCR is catalytically active is lowered (at space velocities indicated) if the inventive arrangement is used. Thus, the invention can function with an aqueous urea solution in the preferred embodiment because the adverse effects of dropping exhaust gas temperature is not as harmful to the reduction system as it would otherwise be,